THE EFFECT OF BREATHING 100 PERCENT OXGEN
ON
SHORT TERM MEMORY OF MILITARY OFFICERS

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THESIS

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ON
SHORT TERM MEMORY OF MILITARY OFFICERS

by

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Thesis Advisor: G. K. Poock

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The Effect of Breathing 100 Percent Oxygen
on
Short Term Memory of Military Officers

by

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Lieutenant Commander, United States Navy
B.A., Kalamazoo College, 1963

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I. THE PROBLEM

A. PHYSIOLOGICAL AND OTHER EFFECTS OF 100 PERCENT OXYGEN ON MAN

The breathing of 100 percent oxygen has been reported to cause adverse physiological and psychomotor effects in normal human beings. In this section, a number of effects will be discussed and proposed causes will be examined. Causes for all effects are far from being completely understood.

One of the interesting effects of high oxygen concentration in the blood has been reported by Lambertsen, et al. (1953) and supported by Womack (1961). Lambertsen reports:

> "Since Paul Bert first demonstrated that generalized convulsions can be produced by prolonged inhalation of oxygen at pressures greater than 1 atmosphere, the paradox of central nervous system intoxication by an excess of this essential gas has stimulated much experimentation and debate."

Lambertsen's research demonstrated a 15 percent decrease in cerebral blood flow after one hour exposure to 100 percent oxygen at sea level pressure; and a 25 percent decrease in cerebral blood flow at 3.5 atmospheres of pressure. The effects occurred with no significant loss of oxygen to the brain. Lambertsen proposed the effects as direct causes of convulsions. Citing this research and others, Womack suggests using only a 35 to 50 percent concentration of oxygen in treating certain medical problems due to the anticipated dangers of using 100 percent oxygen in treatment.

Comroe, et al. (1945) discussing oxygen toxicity effects at sea level and at 18,000 feet altitude, further lend support to adverse effects of breathing pure oxygen for periods of time greater than 24 hours. An interesting result of this study is that the effects reported were not present at the higher altitude. Among the effects demonstrated on healthy subjects between 19 and 31 years of age were sub-sternal distress (described as an ache behind the sternum that became sharp and severe during inhalation); cough, sore throat and nasal congestion; eye irritation, fatigue, pain in joints (as in bends), tingling in the extremities, muscle pains, hoarseness, and dizziness or lightheadedness. While these effects were not universal in all 90 subjects observed, the percentage of occurrence in most cases was significant. The authors of this study made the following observation:

> "We feel that the clinican must bear in mind that oxygen is a drug and must be used in accordance with well recognized pharmacologic principles; i.e., since it has certain toxic effects and is not completely harmless (as widely believed in clinical circles) it should be given only in the lowest dosage or concentration required by the particular patient."

The authors stated that use of 100 percent oxygen for short periods is probably safe.

Dunn (1962) examined the proposition that gaseous nitrogen produces a degree of narcosis under normal or reduced pressures with the administration of several oxygen-nitrogen mixtures. The oxygen concentrations in the mixtures were 20, 25, 34, 40, 50, 60 and 80 percent. One result indicated that subjects who breathed oxygen-enriched

air suffered less fatigue in performing the experimental task (a monitoring and motor action task requiring a sustained effort and a high level of alertness) than those without the enriched air. This result conflicts with the report of Comroe, et al. discussed above, but is in agreement with that of Bills (1937). It was interpreted by Dunn as follows:

> "Such effects, although empirically firm, are not readily understood. They may be due to an increase in the amount of oxygen dissolved in blood plasma, or, as suggested by Hauty, et al. they may reflect compensation for the custom among flying personnel of breathing highly oxygenated air to offset fatigue."

These results, while contrary to many of the current reports, help to illustrate some conflicting hypotheses that have been made concerning oxygen toxicity. They also point out the need for further study.

Other effects of oxygen on the body and body functioning are discussed under separate headings below.

1. <u>Vision</u>

Miller (1958) and Beehler, et al. (1963) studied the effects of high oxygen concentrations from two viewpoints: Miller from the standpoint of visual field and visual acuity, while Beehler studied physiological effects to the eye. Miller's finding was that use of 100 percent oxygen for periods up to four hours had no significant effect on visual field or acuity. Beehler reported profound eye damage in mature animals after exposure for 48 hours to 90-100 percent oxygen. Beehler made no direct comparison to possible similar effects in man.

2. Psychomotor Performance

In an experiment performed by Scow, et al. (1950) using subjects breathing 100 percent oxygen at sea level and at a simulated altitude of 35,000 feet, no difference was found in performance on four tasks between the two altitudes. The four tasks were:

a. A Flicker Fusion Frequency Threshold Test.

b. A pursuitmeter (a revolving drum with an irregular slot in it which was followed by a pointer controlled by the subject).

c. Tremor (tested by an apparatus consisting of a pointer held by the hand in a small hole in a metal plate).

d. Tapping (tested with a flat metal plate and a pointer with which the subjects tapped the plate as rapidly as possible for 45 seconds).

SUMMARY. A review of the literature on physiological and psychomotor effects of breathing high oxygen concentrations for lengths of time from one hour to 48 hours reveals evidence for adverse physiological effects of oxygen. There is also experimental evidence for expecting no effect in such areas as visual acuity, visual field and psychomotor performance.

In a significant departure from the results cited above, Poulton (1974) reported that while breathing 100 percent oxygen during performance of a short-term memory task, a statistically significant decrement in short term memory capability was demonstrated. This decrement occurred over as short a period as eight minutes. If this result

represents a fact and can be duplicated, its implications for users of 100 percent oxygen are significant. Among the users are military jet pilots who breathe 100 percent oxygen continuously while in the air. Poulton's results provided the basis for the present research. Prior to describing the methods used to test the hypothesis of no oxygen effect, a number of major theories and models of short term memory will be reported, as well as the results of research into short term memory.

B. THEORY OF SHORT TERM MEMORY

1. Definition of Terms

Short term memory (STM) is a function of consciousness without which one could not perform successfully. STM leads to a longer term store of events, actions, patterns and other phenomena. STM is fed by stimuli which, according to a number of theories, are processed before they reach storage to become part of conscious recall. Fitts and Posner (1967) defined STM as "a system which loses information rapidly in the absence of sustained attention." They reported a first type of storage as being a sensory one:

> "At the neurophysiological level, electrical phenomena associated with sensory stimulation of short duration, such as a click or a 1-millisecond flash, persist for at least several hundred milliseconds after the event."

It has been shown (e.g., the book by Vance Packard entitled The Hidden Persuaders) that such stimuli may not reach a conscious level in the individual. Beyond this

phenomenon are short and long term memory capabilities. The purpose of the present experiment is limited to the study of memory of short duration, or short term memory.

The terms used to characterize short term memory differ among researchers. Some use short term memory. Others use the term primary to label the short term store. A number of researchers view STM as a span, while others refer to the capacity of STM as a limit. STM is conceptualized as a trace by theorists such as Brown and Welford. All of the terms cited above are used in the present paper.

The question may arise: How short is STM? The duration has been specified by theorists as periods from a few seconds to several minutes. Fitts and Posner defined the term as about 60 seconds. More often STM is referred to in terms of its capacity, or span. Fitts and Posner reported that, for college age students, the maximum number of items that can be stored with 50 percent accuracy was seven or eight. The number of items can be expanded to 10-12 items with practice (depending on the type of item to be memorized). The number seven has been proposed by Miller, as reported in Norman (1969), as significant for the limiting number of many kinds of items that can be memorized.

STM is essential to human functioning. Examples of tasks involving STM are: a) "on the spot" diagnosis of equipment malfunctions; b) predicting tracks and future positions from an air traffic display; or c) being told a string of digits, a phone number, or a number to be entered

into a calculator that is used in a matter of seconds (VanCott, et al., 1972).

STM has been experimentally studied from a number of points of view. One is designed to test the item capacity of the store. Fitts and Posner illustrated the method of testing the item capacity.

> "In a traditional memory-span experiment, a series of auditory or visual stimuli is presented at the rate of one item per second. As soon as the last item has been presented, the subject is asked to repeat the series in the order in which it was given. The number of items is varied to determine how many of them can be repeated without error half the time. This task closely resembles the everyday experience of looking up a telephone number."

A second method for studying STM is to test the effects of intervening, or interpolated, stimuli on material to be remembered. A third approach, serial short term memory, will be discussed later.

2. Theories of Short Term Memory

Broadbent (1971) separated the study of STM into pre- and post-1958. Following Brown (1958), Broadbent proposed that memory for more than a few seconds (i.e., STM) was facilitated by rehearsal. During rehearsal items to be remembered were continuously recirculated between a buffer storage, just after reception by the sense organs, and a limited capacity storage system. If intervening items were presented during rehearsal, a number of the original items would be lost from memory. Otherwise the original items would gradually be transferred to a longer term storage system.

A modification to the basic theory came with the advent of information theory and its application to human performance. In Broadbent's words:

> "In the context of time, there was one apparent difficulty in such a theory (his original theory: author's note), namely that the speed with which each item could be recirculated through such a system ought to depend upon the amount of information per item."

Miller showed that information content was not the critical element in STM due to processes called "chunking" and "coding" of information. These terms will be clearly defined below.

Since 1958 there has been a proliferation of writing on STM. Broadbent synthesized the results of the writings into areas of agreement and areas of disagreement. Of importance is that studies have been conducted concerning the effect of interference on material to be learned. Interference has been widely accepted as a technique for analysis of STM. In addition, the existence of a buffer store and coding process have been generally accepted. "If an item has been presented, it will enter this early stage of buffer storage, but unless some further process takes place within the first second or so, the item will be lost." (Broadbent, 1971). The "further process" that Broadbent refers to is coding. Norman, quoting from Miller's paper to which previous reference was made, discussed the process of coding. (NOTE: coding takes place before the item's entry into a conscious level.) From Norman:

"The differences between our ability to retain things in immediate memory result from differences in the types of information processing involved. When we try to make an absolute judgment we are trying to encode information. That is, we are trying to categorize the stimulus input according to previously learned classifications."

Norman stated that the encoded information is the material that is stored. Norman hypothesized that "we can improve our apparent memory span by recoding or 'chunking' information"; chunking used as defined by Miller. Broadbent argued that coding (in his terms "classification") occurs during perception of the item. Perception occurs after the item's initial pass through the buffer store and before the item is recirculated to the buffer store.

In citing areas of disagreement since 1958, Broadbent identified the nature of memory once a stimulus has been categorized while it is vulnerable to intervening activity.

"Is memory at this stage to be explained by the recirculating process championed by Broadbent (1958), albeit with a change in the recirculating information from its original sensory form to its new transformed and categorized version? Or is it possible to argue that, once a stimulus has been categorized, the information enters a simple memory system whose principles remain the same between periods of a few seconds and periods of days or weeks?"

In the final conclusion Broadbent returned to his position of 1958 supporting the existence of a buffer store, a short term memory and a long term memory store (three stage system). This view is held by a number of researchers today, although some refer only to short and long term stores.

Before moving from the discussion of theories of STM, some of the issues, or sub-theories, contained within the study of STM will be addressed.

a. Rehearsal

The importance of rehearsal in STM has already been stated. Virtually all of the theories of STM acknowledge the necessity for rehearsal in maintaining a short term store. A number of experiments have addressed rehearsal and the processes of interference with rehearsal. Brown (1958) found that leaving an interval of from 2-5 seconds between presentation of a stimulus and presentation of intervening stimuli substantially improved the recall of the original stimulus. In other research, Peterson and Peterson (1959), Murdock (1961) and Sanders (1961) report the maintenance of STM given rehearsal. Welford (1968) states:

> "The reasons for these rehearsal effects are not, however, entirely clear. To some extent rehearsal may serve to keep the memory traces from decaying, but this cannot account for the increased resistance to interference from intervening activity. Brown reported that many of his subjects made remarks which implied that they were somehow recoding the material during rehearsal or were applying mnemonic devices such as forming associations -- he mentions one subject who associated the letters ND with the words 'National Debt'."

Rehearsal can occur vocally or subvocally. The subject in an experiment can be observed or heard vocally repeating stimuli to be remembered. The subject's lips may also be seen moving in subvocal rehearsal. The subvocal rehearsal is a type of inner-communication rather than a conscious rehearsal. Both forms of rehearsal play an important part in STM.

b. Decay Versus Interference Theories of STM

Two opposing views of how material is lost from the short term store are the decay theory and the interference

theory. Decay theory proposes that material is lost from memory as a function of time. Interference theory attributes loss of material to interference from events occurring after presentation of material to be memorized.

The decay theory has been tested experimentally by a number of researchers. Brown (1958) provided one of the earliest detailed descriptions of the theory. From Brown:

> "The basic hypothesis of this theory is that when something is perceived, a memory trace is established which decays rapidly during the initial phase of its career. (By memory trace is meant only the neural substrate of retention, whatever this may be.) Some decay of the trace is assumed to be compatible with reliable recall -- just as partial fading of print may be compatible with perfect legibility. But recall will cease to be reliable if decay of the trace proceeds beyond a critical level ... . The hypothesis of rapid decay of the memory trace, however, also provides a possible solution to (problems of origin and nature of the immediate memory span, and why we forget when this span is exceeded: author's note) ... and one which has the merit of simplicity. The hypothesis leads to a theory of the memory span which in outline runs as follows: When a sequence of items is presented, the interval between the perception of each item and the attempt to recall that item will depend on the length of the sequence. If the sequence exceeds a certain length, decay of the memory traces of some of the items will proceed too far for accurate recall of the sequence to be possible. This length is the memory span. Thus the trace-decay hypothesis can explain both the origin of the span and why forgetting occurs when the span is exceeded."

Opposition to Brown's decay theory has come from interference theorists. Interference theorists support studies that attribute loss of material from the short term to pro-active and retro-active inhibition. Pro-active inhibition is defined as interference with required performance caused by material learned or remembered prior to the time

of the required performance. Retro-active inhibition refers to interference with required performance caused by material learned or remembered subsequent to learning the original required response.

Norman and Welford attacked the decay theory on differing grounds. Welford cites experimental evidence gathered by a number of researchers and states:

> "On reflection ... the evidence (for Brown's theory: author's note) is unconvincing. One would expect that, if time alone was important, halving the rate of presentation and reproduction (of digits) would halve the span. This it clearly does not do. What is more, a number of studies have found that memory span falls rather than rises with increased rate of presentation."

Welford stated that time, by itself, may prove to be an "unnecessary" cause of the limitation of the short term memory span.

Norman made the following statement:

> "It is, of course, very difficult to distinguish a theory which postulates decay caused by interference, primarily because it is not possible to do the one critical experiment which everyone would accept. The critical experiment would be to present material to a subject, have him do nothing for some period of time, and then test his retention of the items. The interference theorist would predict no loss; the time theorist would predict substantial loss. The catch is that it is not possible for a subject to 'do nothing'. Rehearsal, thinking, conscious and unconscious processes all occur continually. There is no simple switch we can throw to turn a subject 'off' for a short period of time. Who is to say, then, whether any decay in memory is a result of the passage of time or activity?"

c. Serial Short Term Memory

Serial short term memory tasks are defined as tasks involving continuous presentation and retrieval (Fitts and Posner, 1967). Fitts and Posner illustrated two

general methods employed in studying serial STM. The first is the running memory span method in which subjects recall items presented in continuous series. Recall is made of as many items as possible in the series on the experimenter's signal. Another method of testing the running memory span is for the subject to recall specific items from a continuously presented list. The second method involves the subject responding, as in typing, to a list presented in which there must naturally occur a lag between stimulus and response.

A number of experimenters have studied serial STM; among them Pollack, et al., and Poulton (both cited in Fitts and Posner); and Kay as reported in Welford (1968). Pollack's group found that, on a running memory task, subjects could recall the last three or four items of a list that was terminated suddenly. Poulton found the following results, quoted from Fitts and Posner:

> "Subjects printed the words they heard from tape recordings. The speed was increased so that the subjects fell farther and farther behind as they worked. Instructions were to go as far as possible, then skip and pick up the dictation at a later point. The experimenter measured how far behind the subjects were able to lag before they had to skip. The results showed that on a first hearing, the best peformance for a group of subjects averaged about thirty-five letters, while the best subject attained a span of fifty-four correct letters."

Kay used a task similar to that used by Poulton (1963) but with different apparatus. The results obtained were similar to Poulton's: a subject trying to recall a stimulus presented more than three back in a series (at fixed pace) had great difficulty. Both experimenters attributed poor

performance on such tasks to lack of ability to rehearse items to be remembered. This is presumed due to intervention of additional stimulus items to be remembered.

There is a difference between serial STM and the types of STM tested by retention of individual items or items in blocks. The serial memory task was employed in the experiment reported in the present paper as well as in Poulton's (1974) experiment. The present research is based on Poulton's work.

C. THE PRESENT PURPOSE

The present experiment was designed to test the hypothesis that there is no effect (decrement) in performance of subjects on a short term memory task caused by progressive effects of breathing 100 percent oxygen. The methods and procedures were similar to those used by Poulton (1974). Poulton's experiment was conducted to determine the cause of failure of men to follow procedures in emergency escapes from submarines. Part of the procedure was for men to carry out a sequence of actions while breathing 100 percent oxygen from a portable oxygen bottle. It was supposed, as a possibility for the failures, that men would forget some step or steps in the sequence, or that they would perform the steps in the wrong order. A possibility for this confusion was the use of pure oxygen. The results of Poulton's experiment showed that breathing pure oxygen for as little as eight minutes caused a statistically significant decrement in performance of a difficult short term memory task.

In the present experiment subjects breathed 100 percent oxygen while performing a serial short term memory task. The task was for subjects to remember symbols presented in a random sequence. The sequence speed was controlled by the subject (subject paced). The lag conditions were similar to those used by Poulton. The stimuli, four different symbols, were presented on a testing device called Response Analysis Tester (RATER). The device will be discussed later.

A pre-experiment was conducted to determine whether colors or symbols should be used as stimuli in the main experiment. If a significant difference were found in subject's performance between colors and symbols, the choice of stimuli would be the set that provided the most difficulty. If no difference were found then the choice would be symbols since symbols are more widely used than colors in military computer-generated aircraft displays. Other purposes of the pre-experiment were: to test the adequacy of taped instructions to the subjects; to ensure that the timing sequence of the experiment was appropriate; and to ensure that subjects could adequately perform the experimental conditions. Procedures were identical to those used in the main experiment with the exception that oxygen was not used.

Fourteen subjects were employed in the pre-experiment, seven each using colors and symbols. The results indicated no significant difference in subject's ability to perform the task between colors and symbols. Thus the choice of stimuli for the main experiment was symbols.

The purpose for conducting this study should be clear when it is understood that pilots and crewmen of all military jet aircraft are supplied with 100 percent oxygen for the duration of their flights: i.e., periods ranging from one hour to four or five hours or more. If breathing 100 percent oxygen caused adverse effects on short term memory over eight minutes, this fact should be clearly established and action taken to correct this potentially destructive situation. The present experiment was designed to test for the adverse effects of oxygen on short term memory.

II. METHODS

A. DESIGN

Data from the present experiment was analyzed according to a three-way factorial analysis of variance (ANOVA) with repeated measures on two factors (Winer, 1962, pp. 319-337). The three main factors were oxygen conditions (2 levels), delays (3 levels) and trial sets (3 levels). Figure 1 is a conceptual model of the experiment.

The dependent variable for the study was a "percent correct" score, i.e., number of correct responses divided by number of total responses. Percent correct was used since a measure of subject accuracy was desired.

The subjects were divided into two groups, one using 100 percent oxygen during all trials and delays, the other using ordinary air. There were eighteen subjects in each group. Subjects were assigned to the oxygen and air groups by random selection after isolating them into four distinct experiential groups. The experiential groups were based on experience with an oxygen mask (pilots of jet and propellor driven aircraft), previous use of 100 percent oxygen and nationality. Table I is a listing of the groups and the numbers within each group.

As a final control measure the average age of each group was equalized. The average age of the groups were: oxygen group, 30.40 years; air group, 30.68 years.

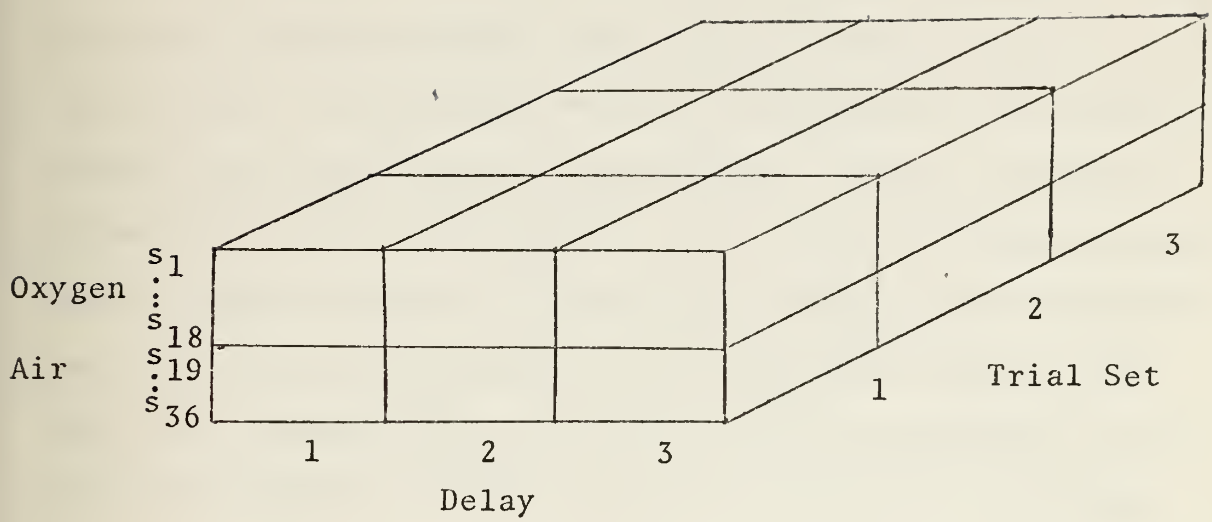

Figure 1: Conceptual Model of the Experiment

GROUP	TOTAL	OXYGEN GROUP	AIR GROUP
Jet Pilots	7	3	4
Prop Pilots	9	4	5
U.S. Army/Navy Surface	11	6	5
Foreign	9	5	4
TOTAL	36	18	18

TABLE I: Subject Categories and Assignment to Experimental Conditions

B. SUBJECTS

The subjects for the experiment were 36 male students from the Naval Postgraduate School. Subjects ranged in age from 26 to 40 years. Each subject was required to participate

in the experiment as part of the course completion requirements in OA-3657 (Human Factors in Systems Design I). They were not compensated for their time. Subjects were told that the purpose of the experiment was to determine the effect of wearing an oxygen mask on performance. It was considered necessary to tell the subjects that they may be using oxygen due to unequal previous experience. Judging from comments made by subjects during the data collection none of them correctly guessed the real purpose of the experiment, nor were they aware of whether they were using air or oxygen.

C. STIMULI AND APPARATUS

1. Oxygen Equipment

The oxygen apparatus used is standard Navy equipment. The mask was a pressure breathing oxygen mask MS 22001-6, manufactured by Sierra Engineering Company. Two sizes of masks were available for use, medium and large. The oxygen regulator was an automatic positive pressure diluter demand type, manufactured by Bendix Aviation Corporation. The regulator has two settings for oxygen, normal and 100 percent. The regulator was set to 100 percent for the duration of the experiment. Normal breathing air was fed from an air bottle through the oxygen regulator to the mask. Oxygen was fed from oxygen tanks through the regulator to the mask. The mask was held onto the face of the subject with standard fittings attached to a cup on the mask, and then to a helmet

worn by the subject. The helmets were ordinary flight helmets worn by crews of military aircraft.

2. Miniaturized Response Analysis Tester (RATER)

The experimental device used was the Response Analysis Tester (RATER), Model 3. The device, built by General Dynamics Convair Division, is a psychomotor testing instrument designed to provide reliable measurement of impairment of response speed/accuracy and short term memory for patterned or colored stimuli. The basic task required the subject to press the correct response button for each of four symbols. The symbols were automatically displayed in continuous random sequence. A card indicating the correct response buttons was placed under the response button panel and remained in place throughout the experiment. Total responses and correct responses were determined from counters installed in the control unit.

Figures 2, 3, 4 and 5 are photographs of the equipment used during the experiment. The symbols presented by the RATER were a plus sign, a diamond, a triangle and a circle. The symbols were white colored and were presented against a dark background.

D. PROCEDURE

The experiment was conducted in the Man-Machine Systems Design Laboratory at the Naval Postgraduate School. Subjects were required to perform three experimental delay conditions. Each of the three delay conditions was performed on separate

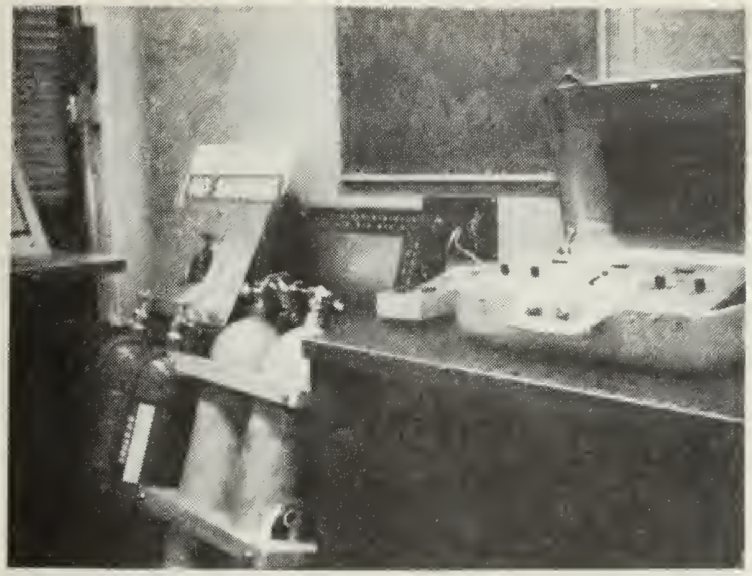

Figure 2: Setup of the RATER Control Unit with Oxygen and Air Tanks Outside the Isolation Booth

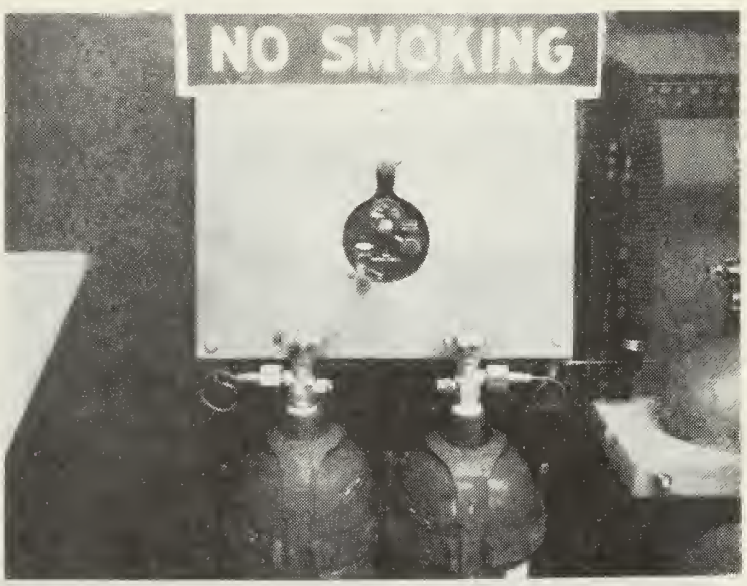

Figure 3: The Oxygen/Air Regulator Mounted above the Oxygen Bottles

Figure 4: The RATER display unit, with inter-communication box, oxygen mask and helmet.

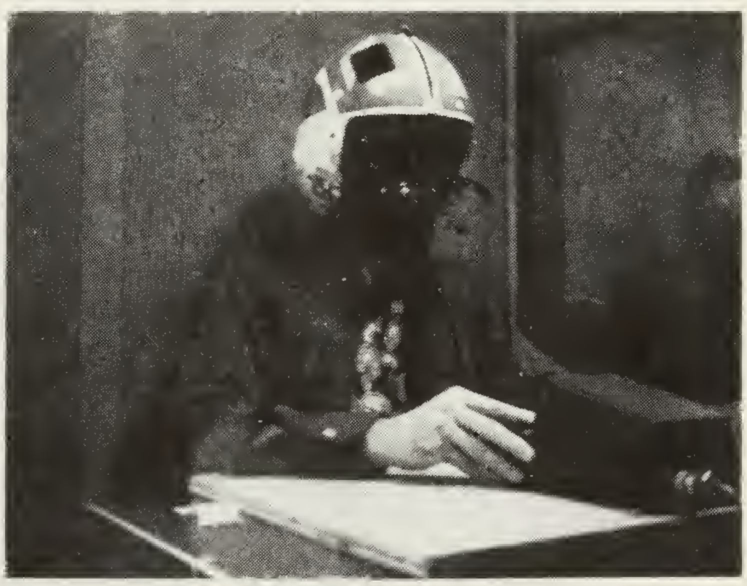

Figure 5: A Subject Seated at the RATER Display Unit Wearing Helmet and Mask

days to prevent residual effects of oxygen from affecting performance of subjects for more than the desired experimental time.

On the first day each subject received practice in each delay condition (1 to 3) in addition to a familiarization session. During the familiarization session a condition called delay 0 was performed. In delay 0 the subject responded to the symbol that was currently displayed. The two minute work periods at each delay condition were separated by two minute rest periods. During this time the subject received instructions for the next work period. The oxygen mask was not worn during practice sessions.

Following the initial practice session each subject was given two additional two minute practice sessions performing the delay condition specified for that day. This was to build proficiency at the task. Then the mask was donned and either air or oxygen was supplied while the subject performed three work sessions at the specified delay condition. Each work session was separated by a two minute rest period. Thus subjects were exposed to pure oxygen for a total of 12 minutes. A diagram of the sequence of the experimental sessions is included in Figure 6.

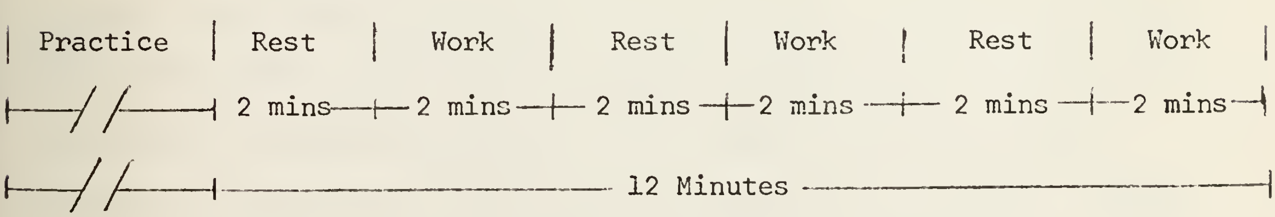

Figure 6: Sequence of Experimental Sessions

Performance of delay conditions was randomized for each subject on each day: i.e., one third started on the first day with delay 1, one third with delay 2, and one third with delay 3, etc. The order of delay presentations for each subject was also randomized. Through randomization it was hoped that uniformity of performance on all variables other than the dependent variable would be achieved.

On the three days of the subjects' participation in the experiment the basic time sequence described in Figure 6 was followed. Each subject received two-2 minute practice sessions on the delay condition specified for a given day. A description of the subjects' task on each delay condition follows.

1. Delay 1

The subject first viewed an amber "ready" light for three seconds, followed simultaneously by a green "test" light and the first symbol. This symbol was present for one-and-one-half seconds. The subject was instructed not to respond to the first symbol at this time, but to delay response until the next symbol appeared. The next symbol was displayed for an indefinite period of time until the correct response to the first symbol was made. The present symbol would dim momentarily indicating a correct response, then the next symbol would automatically appear. If an incorrect response were made the symbol maintained its original intensity indicating an incorrect response. This sequence was maintained for a two minute period.

2. <u>Delay 2</u>

Delay 2 was similar to delay 1 expect that the subject first viewed two symbols for fixed periods of one-and-one-half seconds each. No response was to be made until the third symbol appeared. At this time the subject was to respond to the first symbol displayed, and when the fourth symbol appeared the subject was to respond to the second symbol, and so on for a two minute period.

3. <u>Delay 3</u>

Delay 3 was similar to delays 1 and 2 except that the subject viewed three symbols for fixed periods of one-and-one-half seconds each. When the fourth symbol appeared subject was to respond to the first one displayed, and when the fifth symbol appeared subject was to respond to the second one displayed, and so on for a two minute period.

The instructions to the subjects were taped so that each subject received identical instructions. The instructions are included in Appendix A.

III. RESULTS

The results indicated no significant difference between breathing 100 percent oxygen and breathing air for a period of 12 minutes. This result was consistent in all three delay conditions. The ANOVA table is included in Table II.

Results of a Duncan Multiple Range test performed on the means of the delay conditions showed significant difference between all means beyond the .01 level. This result can be seen graphically in Figure 7. It is noted that differences between air and oxygen treatments at each delay condition are nearly non-existent over the 12 minute periods. Differences between delays are marked.

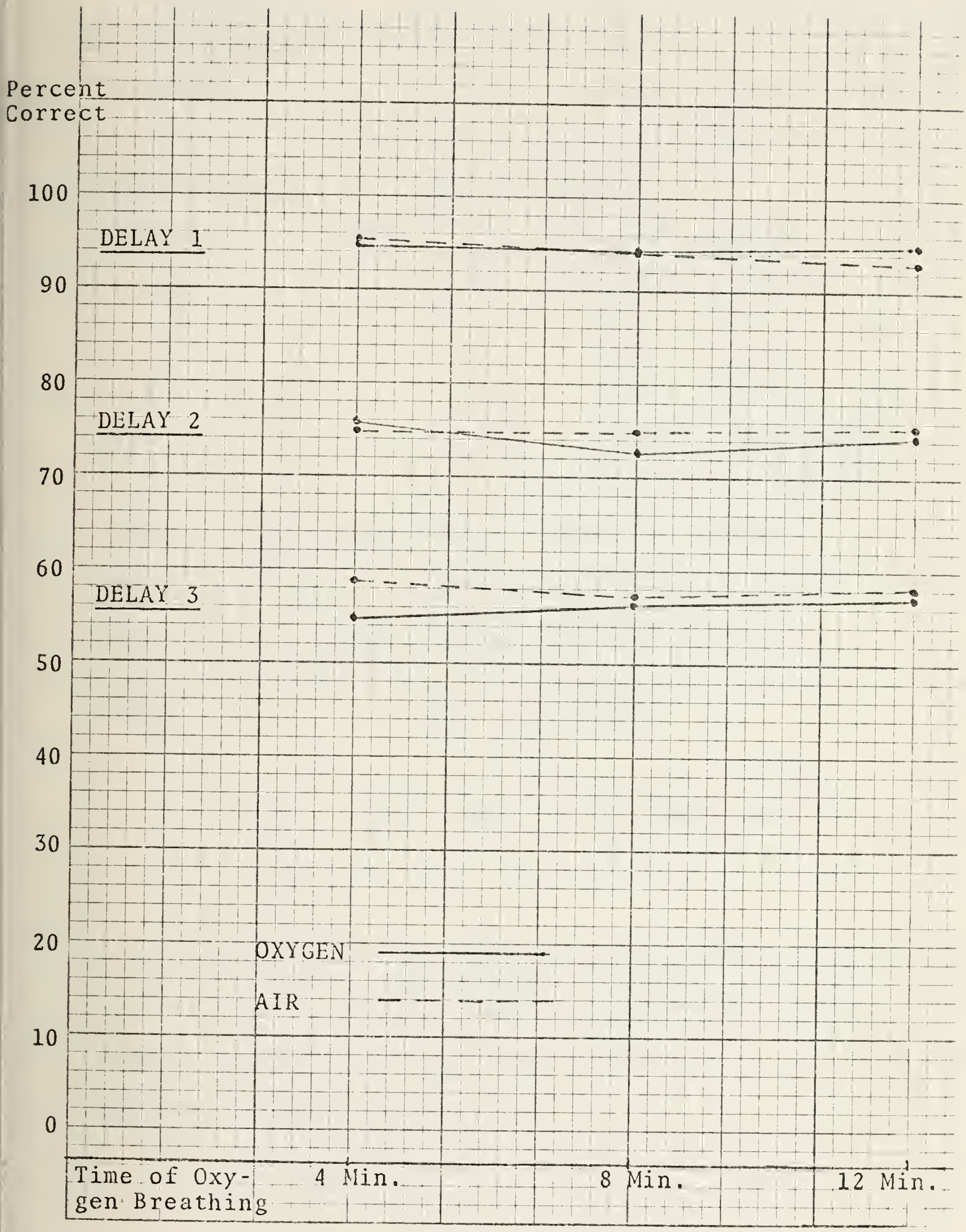

Figure 7: Percent Correct Responses

SOURCE	d.f.	S.S.	M.S.	F	P
Between Subjects	35	85811.19			
Oxygen	1	38.58	38.58	0.02	
Error	34	85772.61	2522.72		
Within Subjects	288	29418.92			
Delays	2	3943.60	1971.80	7.15	$<.05$
Trials	2	54.80	27.40	1.17	
O x D	2	743.26	371.63	1.35	
O x T	2	20.85	10.43	0.45	
D x T	4	74.61	18.65	0.61	
O x D x T	4	81.85	20.46	0.67	
Error (O x D x Subj)	68	18751.36	275.76		
Error (T x Subj)	68	1593.21	23.43		
Error (D x T x Subj)	136	4155.38	30.55		
TOTAL	323	115,230.11			

TABLE II: ANOVA Table for the Main Experiment

Tables III, IV and V list the mean and standard deviation of total responses, correct responses and percent correct responses for both air and oxygen groups over the three delay conditions and the trial sets.

		TRIAL 1		TRIAL 2		TRIAL 3		OVERALL	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
	D-1	123.11	35.17	133.61	39.81	142.00	41.82	132.91	39.08
OXYGEN	D-2	89.67	25.06	97.83	28.63	103.17	28.31	96.89	27.44
	D-3	88.89	30.69	92.22	31.64	98.56	34.23	93.22	31.86
	D-1	118.89	31.72	131.39	30.88	135.56	30.03	128.61	31.13
AIR	D-2	91.28	31.77	96.78	30.11	101.89	32.49	96.65	31.18
	D-3	78.50	26.98	79.72	30.94	81.50	32.28	79.91	29.60

Table III: Mean and Standard Deviation of Total Responses

		TRIAL 1		TRIAL 2		TRIAL 3		OVERALL	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
	D-1	116.44	34.99	125.72	39.13	133.22	41.31	125.13	38.46
OXYGEN	D-2	69.17	24.58	70.33	23.93	75.94	25.12	71.81	24.27
	D-3	47.67	17.19	50.22	16.85	55.17	18.20	51.02	17.38
	D-1	113.94	31.74	124.89	33.82	127.17	32.26	122.00	32.52
AIR	D-2	67.22	21.37	71.17	22.18	75.61	23.31	71.33	22.15
	D-3	44.39	13.60	44.44	15.66	46.00	16.74	44.94	15.11

Table IV: Mean and Standard Deviation of Correct Responses

		TRIAL 1		TRIAL 2		TRIAL 3		OVERALL	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
	D-1	94.66	6.93	94.13	6.38	94.97	6.19	94.59	6.40
OXYGEN	D-2	75.95	14.61	72.81	14.09	74.36	14.38	74.37	14.15
	D-3	54.94	12.87	56.11	12.06	57.28	11.25	56.11	11.89
	D-1	95.48	4.72	94.04	9.04	93.07	8.02	94.20	7.42
AIR	D-2	75.01	14.41	74.81	14.72	75.53	13.76	75.12	14.03
	D-3	58.57	13.16	56.92	8.55	57.98	9.76	57.83	10.49

Table V: Mean and Standard Deviation of Percent Correct Responses

IV. DISCUSSION

The results indicated no decrement in short term memory while breathing 100 percent oxygen in the present experiment. The result is contrary to results obtained by Poulton (1974). The explanation for this difference is not easy to interpret. A possible explanation may be that Poulton's discussion of test results with subjects influenced their performance.

Regarding task sufficiency, Poulton points out that a difficult task is required to demonstrate deterioration of STM due to oxygen. The task required by the RATER is comparable in difficulty to the task required by Poulton's apparatus. The level of difficulty of delay 3 met the requirements stated by Poulton (1964): i.e., average performance was near 50 percent for both control and experimental groups.

The percent correct figures for the present experiment compare favorably with those of Kay (1953) as reported by Welford (1968), and those of Mackworth and Mackworth (1959) at the slow speed. Kay, using a fixed pace task (1.5 seconds between stimulus presentations), had subjects facing a row of 12 light bulbs with a Morse key directly under each light. The keys were numbered 1-12 in order. Subjects responded to the stimulus just presented, or to the one prior to the one just presented, and so on. In the most difficult condition subjects responded to the stimulus that

was present four back from the one currently displayed. Kay's results are summarized in Table VI.

1-Back	2-Back	3-Back	4-Back
95	67	47	35

Table VI: Percent Correct Responses out of a Total of 36 by 58 Subjects. Results of Kay (1953)

Mackworth and Mackworth (1959) studied the number of items subjects could simultaneously remember in a continuous task similar to that of the RATER. The pace was fixed by the experimenter with two speeds studied: fast (responses required every 1.5 seconds) and slow (responses required every 3.0 seconds). The subject was required to remember previous stimuli presented in delays of 1, 2, 3 and 4 stimuli back in a manner similar to Kay's experiment. Table VII contains Mackworth and Mackworth's results.

Speed	1-Back	2-Back	3-Back	4-Back
Fast	67	38	31	26
Slow	97	77	53	52

Table VII: Percent Correct Responses, from Mackworth and Mackworth (1959)

Of interest in the present experiment is the response times of subjects in the self-pace mode. Average correct

response rates are listed in Table VIII for each delay condition in the oxygen and air groups. Such information provides an indication of the difficulty of each task.

	Delay 1	Delay 2	Delay 3
Oxygen	0.96	1.67	2.35
Air	0.98	1.68	2.67

Table VIII: Average Correct Response Rates, in Seconds

Post hoc analyses were performed using other indicants of the dependent variable. One indicant used successfully by Waldeisen, et al. (1967) involves subtracting twice the number of errors committed from the number of correct responses. The method is a means of correcting for subjects who stress speed over accuracy, or vice versa. The results of the 3-way factorial analysis of variance (the same design used with the percent correct data) performed on the data obtained by this method were similar to those using percent correct: i.e., differences between delays were found significant at the .01 level. No other factors (trials or oxygen condition) were significant, nor were the interactions. Thus greater confidence is warranted in the results of the present experiment as a result of this finding. Figure 8 presents the graphical results of this conclusion.

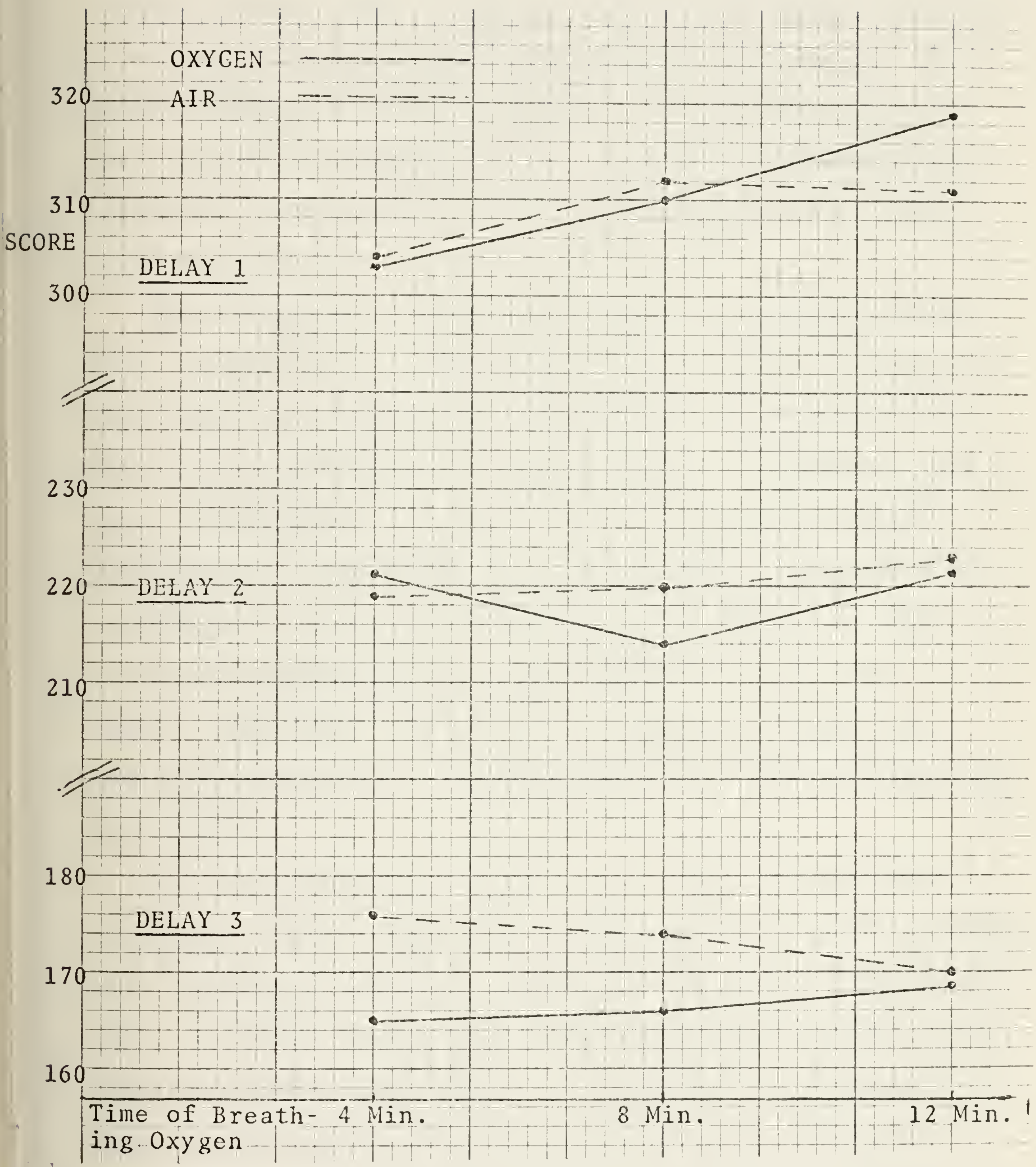

Figure 8: Score = # Right - 2 (Total Resp. - # Right) + 200

A second post hoc analysis involved use of an arcsine transformation to convert the raw percentage scores into radians (Winer, 1962, p. 221). Three way factorial analysis of variance (the same design used above) performed on the radians indicated similar results to those obtained using the previous two methods: i.e., delays were significantly different at the .005 level. No other significant differences were found.

Since Poulton's (1974) experiment was conducted fixed pace, it may be that different results could be obtained if the present experiment were performed using fixed pacing. This is an area requiring further study. Considering the tasks of military jet pilots who use 100 percent oxygen continuously while in the air, self pacing of responses to information presented is more likely the manner in which responses are operationally made than in a fixed pace manner. Therefore the results of the present experiment should be predictive of performance in the actual operating environment.

A 2 way anlaysis of variance with repeated measures on one factor (Winer, 1962, pp. 302-318) was performed comparing four subjects who verbally rehearsed aloud with four who did not. The main factors were verbal rehearsal aloud/no verbal rehearsal aloud, and delays. No significant difference was found between subjects who verbally rehearsed aloud and those who did not. Although subjects were not asked whether they rehearsed sub-vocally, it was of interest to observe that

spoken rehearsal did not seem to affect performance on this task.

Performance of this task in each delay condition was apparently affected by pro-active inhibition. The inhibition caused greatest interference in the delay 3 condition. Pro-active inhibition may account for the significant difference in performance between delay conditions. Subjects reported difficulty in performing the tasks if the sequence of symbols was forgotten. The most often reported cause of forgetting was confusion between signals presented and those to be remembered. A number of subjects used runs of the same symbol to help pick up the sequence. Other subjects found runs of the same symbol more confusing than helpful. The reason for this difference between subjects is unknown.

Observation of the graphs for the oxygen treatments in the delay conditions (Figures 7 and 8) indicates that the curves for oxygen-breathing subjects tend upward from the 8 minute point to the 12 minute point. The upward trend may be an initial sign that performance, although not statistically significant, improved in all cases with increased use of oxygen. The trend was not indicated in all cases in the air treatment. It could be that breathing pure oxygen lessened fatigue and facilitated performance in a manner similar to that described by Dunn (1962) and Bills (1937). The conclusion must be hypothesized, however, since it is not borne out statistically. Further study with increased

periods of breathing pure oxygen is required to determine whether the oxygen has a significantly facilitating effect on this task.

The results of the present experiment indicate that there seems little cause for alarm concerning toxic effects of breathing pure oxygen in this type of experiment.

APPENDIX A

INSTRUCTIONS TO SUBJECTS

The following instructions were adapted from Long and Fishburne (1973). The instructions were taped so that each subject received identical instructions for each delay condition.

A. INSTRUCTIONS TO SUBJECTS FOR DELAY 0

RATER is a test of your psychomotor skill. Four different symbols (a plus sign, a circle, a triangle and a diamond) will appear in a continuous random series in the viewing window. Each of the four response buttons below the viewing window corresponds to one of the four symbols. Your task is to respond to each symbol as it appears by pressing the corresponding correct button.

When you press the correct button for the particular symbol, the symbol will dim and upon releasing the button another symbol will immediately appear. If you press an incorrect button, the symbol will not change but an error will be recorded. Continue trying to make the correct response until you obtain the dimming indication and the next symbol appears.

Try to be as fast, but as accurate as you can. Press only one button at a time. If you press more than one button simultaneously, an error will be recorded automatically.

You will be given a series of practice trials in which to learn the correct button for each symbol.

Remember that the sequence of the symbols is completely random. Runs of the same symbol may occur. Do not try to anticipate which symbol will appear next.

Place the thumb and forefinger of each hand on the response buttons. Maintain this position throughout each trial. Watch for the Ready light. A trial begins three seconds later when the Test light comes on. Begin responding when the first symbol appears and continue to respond until the Test light goes off. Each trial will last 2 minutes, followed by a 2 minute rest period. Do you have any questions on this procedure?

B. INSTRUCTIONS TO SUBJECTS FOR DELAY 1

Now that you know how to operate the RATER in the self-pace mode, you are ready for a new kind of problem which is called the delay mode. In the delay mode, your task is to note the symbols as they are presented but to delay your response until one or more symbols have intervened. You will be told how long to delay your response. For example, with a one-symbol delay in the selfpace mode, a symbol will appear which you should note and remember. When the next symbol appears, your response should be the normal correct response to the previous symbol, no longer present. At the same time, note the symbol present since it will determine the correct response for the next interval. In other words,

you are responding in a continuous sequence as before, except that you are delaying, or shifting, your sequences of responses by one symbol. The same principle applies for delays of two, three and four symbols which you may be asked to learn after you have mastered the one-symbol delay. To start responding in the delay mode, you must view one or more symbols prior to your first response. In the selfpace mode, RATER presents the required number of symbols and then holds the following symbol until you make your first correct delayed response.

In the first set of trials we will do now, you are to respond to the symbol that was present just before the one that is on now. In this case the first symbol will appear and will be on for one-and-one-half seconds, followed by the second symbol. The second symbol will be displayed for an indefinite period of time until you respond correctly to the first one that was displayed. Then the third symbol will appear, and then you must respond to the second one that was on; and so on, so that you are always responding one back from the one that is presently displayed.

Do you have any questions on the next set of trials?

C. INSTRUCTIONS TO SUBJECTS FOR DELAY 2

In this next set of trials your task is to respond to the symbol that was displayed two back from the one that is currently displayed. In this case you will see the first symbol for one-and-one-half seconds, followed by the second symbol for one-and-one-half seconds, and then the third one

will appear. When the third one appears you respond to the first one that was presented. And when the fourth one appears you respond to the second one that was presented; and so on, so that you are always responding two back from the one currently displayed.

You are reminded that you are to respond as accurately but as rapidly as possible. Do not try to emphasize either speed or accuracy, but try to work for a good combination of both.

Do you have any questions on the next set of trials?

D. INSTRUCTIONS TO SUBJECTS FOR DELAY 3

On the next set of trials you are to respond to the symbol that was present three back from the one that is currently displayed. In this case you will see the first symbol for one-and-one-half seconds, followed by the second symbol for one-and-one-half seconds, and the third symbol for one-and-one-half seconds, and then the fourth symbol will appear. When the fourth symbol is on you are to respond to the first one that was displayed. And when the fifth one comes on you respond to the second one that was displayed; and so on, so that you are always responding three back from the one that is currently displayed.

Do you have any questions on this set of instructions?

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